4. A relatively low quartile deviation is usually considered favorable. A small departure below median probably would not often be disastrous. In areas where the quartile deviation is low we say the rainfall is of a dependable type.

5. A knowledge of departure below the median expressed in percentage of the time should be helpful especially in subhumid and semiarid areas, or in places where there is a tendency for a wide departure from the median.

6. A knowledge of departure above median expressed in percentage of the time should be helpful especially where superabundance of rainfall may be harmful to crops or produce floods.

7. Intelligent long-time planning always takes into account as many factors as possible. Rainfall is a variable factor in Nebraska that always must be considered. The more we know about it the better planning we can do. An area with a wide rainfall variability may present fewer hazards if the percentage of variability is known and considered when plans for the future are being made. This variability series of rainfall maps of Nebraska may offer some possibilities in this connection that previously could not so well be taken into account.

THE HURRICANE WARNING SERVICE AND ITS REORGANIZATION

By EDGAR B. CALVERT

[Weather Bureau, Washington, April 1935]

Tropical cyclones are the meteorological monsters of the sea. No other type of ocean storm approaches them in violence and destructiveness, nor in the persistency with which they maintain their form and force. It is a rare thing for one of them that has fully developed to dissolve and disappear over water surfaces in the Tropics. With few exceptions they continue as violent storms until they strike land or pass out of the tropics. They are called hurricanes when they occur in the Atlantic Ocean, Gulf of Mexico, Caribbean Sea, and the Pacific Ocean off the coast of Central America and Mexico; they are known as "typhoons" in the China Sea; "baguios" in the water area of the Philippines and "cyclones" in the Bay of Bengal and other portions of the Indian Ocean. By whatever name they are known and wherever they occur they strike terror into the hearts of seamen and of people who reside along the low-lying shores subject to their visitation.

No one person or organization can surely be credited with being the first to engage in a systematic forecasting program for the purpose of giving warning of the approach of hurricanes. William Reid began his studies of them when on duty on the island of Barbados in 1831. His work published in 1838 is still held in esteem as a book of reference. He studied hurricanes, plotted their courses, and formulated his "law of storms", including rules for mariners to maneuver so as to avoid their centers; and in 1847 he established the earliest system of displaying warnings when the approach of a storm was indicated by the barometer.

The credit for the next warnings is probably due to Father Benito Viñes, who for many years was associated with Belen College at Habana, Cuba. It is known that in 1870, when Father Viñes became director of the college, he began to grapple with the problem of forewarning the people of the advent of hurricanes which threatened them. Before that time the inhabitants of Cuba were accustomed to hear of these phenomena only upon their near approach. This was the same year that the United States Congress made appropriations for organizing a national meteorological service, control of which was vested in the Signal Corps of the Army (later transferred to the Agricultural Department as the Weather Bureau). The Signal Service was scarcely in position to issue hurricane warnings until August 6, 1873. On that date arrangements for securing daily weather reports by cable from Cuba and other islands of the West Indies went into effect with receipt of observations from Habana. Daily reports from Kingston began September 18, and from Santiago de Cuba, on September 29 of the same year. Plans for obtaining reports from Puerto Rico, Guadeloupe, and Barbados did not materialize that year as was expected.

The meteorological service of the Signal Corps did not start functioning until 1870, but almost from the beginning the need for issuing warnings of hurricanes to the people along the southern coasts of the United States was recognized; also that this could be accomplished only by obtaining current observations from islands in the West Indies. Plans for obtaining such observations were discussed in the reports of the Chief Signal Officer for the fiscal years 1872, 1873, and 1874.

Father Viñes had nearly 3 years' start on the Signal Service in organizing his hurricane warning service. According to one of his commentators (Rev. Walter M. Drum, S. J.), the earliest authenticated date on which he issued a warning was September 11, 1875, but it seems likely that he did so prior to that time. There, too, is uncertainty as to the date of the first hurricane warning issued by the Signal Corps. Father Viñes is generally conceded to be the first meteorologist to forecast hurricanes from observations of the upper as well as the lower clouds; also, he was the first to announce that both the place of formation and the direction of movement of hurricanes change as the season advances. The August 1873 issue of the MONTHLY WEATHER REVIEW refers to a forecast issued on August 23, 1873, of stormy weather for the New England and Middle Atlantic coasts "with cautionary signals at Cape May, New York, and New London." This article contains a statement to the effect that the storm was of tropical origin, that it was by far the worst one since the establishment of the Signal Corps and that it "did not occur within the limits of our stations." It is a safe deduction that August 23, 1873, was the date of the first warning issued in connection with a storm of tropical origin but it would not be proper to claim that it was a hurricane warning because the storm was extratropical when the warnings were put out.

Father Viñes is justly placed in the front rank of those who have contributed to our knowledge of tropical storms and have been untiring in their efforts to develop means for forecasting them.

Father Viñes' hurricane forecasting studies were in four directions: First, to find some sign or group of signs that would invariably prove the existence of a cyclone while it was yet at a great distance from the observer; second, to get bearings in regard to the whirlwind, i. e., to determine what part of the horizon it was coming from; third, to locate the trajectory or curve along which the cyclone would move, and to do this in

time for the observer to betake himself to a safe distance from that fatal curve; fourth, to determine the distance of the hurricane from the observer, its intensity, area, and velocity.

A serious setback in the development of the hurricane warning service occurred in 1876 because of discontinuance of observations from the West Indies, due to lack of funds for cabling, but this difficulty was partially overcome by the generosity of the cable companies in granting reduced rates of one-third to one-half of commercial rates.

In 1881 the reports from the West Indies again were suspended partly because of lack of funds but principally because of "doubt being thrown on the legality of spending any part of the appropriations in maintaining a station outside of the limits of the United States." This difficulty appears to have been removed before the next season began. At that time reports were being received from six West Indian localities, namely, Barbados, Guadeloupe, Habana, Kingston, Santiago de Cuba and St. Thomas. In 1888 or 1889 other reports, from Puerto Rico, Santa Cruz, and Antigua, were secured through the newly organized Cuban Meteorological Service which was established January 15, 1889, under the direction of the Naval Observatory of Cuba. From that time onward until the outbreak of the Spanish-American War the records do not disclose any material change in the general operating plans of the hurricane warning service.

In 1898 there was what may be termed the first reorganization of the hurricane warning service. It was due to the Spanish-American War. Prior to that time warnings had been confined to our own coastal areas, although there was courtesy exchange of hurricane information between the Weather Bureau and the Cuban Meteorological Service and Belen College.

Since 1873 observers at West Indian points had been local residents. They were paid for taking the observations but were not subject to any official control by our Government. When war was declared in 1898, it was recognized at once that the hurricane warning service on the old basis would be wholly inadequate to protect the large fleet of naval craft, transports and United States merchantmen operating in the waters subject to hurricane visitations. Accordingly, a bill was drafted and submitted to Congress on June 16, 1898, authorizing the Weather Bureau to establish and operate observing stations throughout the West Indies and along the shores of the Caribbean Sea. The act making appropriations for the service was not approved until July 7, 1898. Permission had to be obtained from various governments for placing trained observers and citizens of the United States at places from which observations were desired. It was obvious that only those whose loyalty and efficiency were beyond question could be given responsibility in such an important undertaking. Much of this preliminary work was done before the appropriation act was passed on July 7, 1898. By vigorous action the first party was started on July 22, 1898, and before the middle of August trained observers of the Weather Bureau had opened stations at Kingston, Jamaica; Port of Spain, Trinidad; Willemstad, Curacao; Santo Domingo, Santo Domingo; and at Santiago de Cuba. Before the middle of September additional stations were operating at Basse-Terre, St. Kitts; and Bridgetown, Barbados. The Weather Bureau forecasting center in the West Indies was located at Kingston, Jamaica.

The war soon was over; in fact, before there was opportunity to issue warnings to our combatant fleet. Nevertheless, there never was question as to the wisdom of the action to provide means for guarding our ships against hurricanes, one of which unannounced might have caused enormous damage. Notwithstanding the cessation of hostilities it was decided to complete the original organization plan. Stations were established at Roseau, Dominica; at San Juan (soon after Puerto Rico came under United States control) and at Colon. Original intentions to place stations at St. Thomas and Barranquilla were abandoned and the station at Colon was closed early in 1899. Headquarters of the forecasting service was transferred to Habana on February 1, 1899. At the same time plans were perfected for giving all parts of the West Indies and ships of all nationalities the benefit of the hurricane warning service of the Weather Bureau. This responsibility has international recognition to this day.

Within a year after the declaration of peace on December 12, 1898, observers began to be withdrawn from the West Indian stations as fast as capable local persons could be trained and qualified to take the observations. In 1902, at the termination of the American occupation, the hurricane forecasting work for the West Indies was transferred from Habana to Washington. All Weather Bureau employees were withdrawn except one who remained for the purpose of completing the substitution of local observers for those sent from the United States. A forecast center for the issuing of hurricane warnings and advices for Puerto Rico and contiguous areas was established at San Juan on June 1, 1919.

Steady improvements were made in the efficiency of the service after the Spanish War. The largest factor in this improvement has been the development of the radio. It has added tremendously to the field of observation. Far greater dependence now is placed on ship reports than on observations from island stations. Ships make regular contributions of two observations a day and additional ones when needed. Last year more than 21,000 observations were received from ships in the southern portions of the North Atlantic, the Gulf of Mexico and the Caribbean Sea during the 6 months which constitute what is known as the hurricane season.

A third epochal change in the hurricane warning service will occur on July 1, 1935. Changes as contemplated on that date are made possible by an item of $80,000 contained in the Weather Bureau portion of the agricultural appropriation bill for the next fiscal year.

Since the beginning of the hurricane warning service in 1873, warnings and advices concerning tropical storms have been issued from Washington, except for the short period during the Spanish War when warnings for the West Indies area were issued from Kingston and Habana, and the service rendered at San Juan since 1919. Under the new reorganization effective on July 1, 1935, no warnings of tropical storms will be issued from Washington except for such as have moved north of latitude 35°N. It is believed that more expeditious, satisfactory, and efficient service can be rendered from forecast centers located nearer to the scene of action than is Washington. Strictly speaking, after that date there will be three hurricane warning centers as follows:

San Juan.—Caribbean Sea and islands east of longitude 75°W. and south of latitude 20°N.

New Orleans, La.—That portion of the Gulf of Mexico and its coasts west of longitude 85°W.

Jacksonville, Fla.—Remaining portions of the Atlantic, Caribbean Sea and Gulf of Mexico areas, islands and coasts south of latitude 35°N.

Jacksonville also will be a district forecast center to include the States of North Carolina, South Carolina, Georgia, and the Florida Peninsula. From that center will emanate all daily weather forecasts, warnings of cold waves, frosts, weekly outlooks, etc., for the States named in addition to storm and hurricane warnings. At present all of this work is being done at theWashington forecast center. Jacksonville also will take over from the Washington center twice daily wind and weather forecasts for the coastal and contiguous ocean zones, Hatteras to Jacksonville; Jacksonville to the Florida Straits; the eastern Gulf of Mexico (east of longitude 85°W.) and the Western Caribbean Sea (west of longitude 75°W.)

New Orleans is now a forecast center for extreme northwest Florida, Alabama, Mississippi, Louisiana, Arkansas, Oklahoma and Texas and storm warnings for the Gulf Coast from Apalachicola westward to Brownsville. Its principal additional work to be transferred from the Washington center will be the hurricane service for the area as heretofore described; also daily wind and weather forecasts for the middle Gulf of Mexico (between longitude 85°W. and 90°W., north of the Yucatan Channel) and for the Western Gulf of Mexico (west of longitude 90°W.) will emanate twice daily from New Orleans instead of from Washington.

The reorganization program involves material changes in the collection of observations from ships. Under existing arrangements observations are secured regularly twice a day throughout the year by radio from a limited number of selected ships in the Atlantic, Gulf of Mexico, and Caribbean Sea. These reports are now transmitted only to Washington. On and after July 1, 1935, selected ships routed south of latitude 35°N. will transmit their observations addressed both to Washington and to Jacksonville. The North Atlantic ships will continue to report only to Washington. Another class of ships, known as cooperative, supplies observations only during the hurricane season, June to November, inclusive. Heretofore service from this class of vessel consisted of two observations a day, taken at 0000 and 1200 G.C.T., and containing only the universal group of data (day of week, octant of globe, latitude, longitude, direction of wind, state of weather, wind force, barometric pressure, visibility and temperature). After July 1, and during the period June 16 to November 15, inclusive, they will take 2 additional observations, at 0600 and 1800, G.C.T., making 4 in all. Observations from cooperative ships will contain the universal data group and also a supplemental group (swell, clouds, temperature difference between air and water, ship's course, barometer change, and past weather). Cooperative ship reports will be addressed only to Jacksonville.

A system of direct calls for special observations from ships when a hurricane is in progress was inaugurated in 1934. It proved to be successful and it will be continued in the reorganization program. This plan, briefly stated, is as follows: The southern portion of the Atlantic, the Gulf of Mexico, and the Caribbean Sea is divided into 5° squares which are numbered. When a hurricane is known to be in progress, commercial radio stations at Galveston, Port Arthur, Tampa, West Palm Beach, and Ensenada (Puerto Rico) are informed of the areas (squares) from which special ship reports are desired and the time the observations should be taken. Operators at these stations contact all ships in the specified squares and ask that the observations be radioed to a specified Weather Bureau forecast center. In this way many valuable reports are secured which otherwise would not be available.

Another feature, not strictly new but on a more systematized basis, will be cooperation with the Coast Guard, whereby weather observations, including data on swells and tides, will be obtained from Coast Guard life saving stations. As a rule observations from Coast Guard stations are not needed until the storm has approached within a few hundred miles of the coast. They will be collected by telephone, telegraph, and radio and speedily will be made available to the forecast centers at New Orleans and Jacksonville. In a similar way there will be cooperation with Coast Guard ships both in forwarding observations taken on board and also in collecting observations from other ships. By a like plan reports from Coast Guard stations, from Cape Fear River northward to the Delaware Breakwater, will be secured for the forecasters at Washington.

An incidental but important part of the program will be the exchange of warnings and advices issued at Washington, Jacksonville, and New Orleans so that each may have knowledge of what the others have done and thereby avoid conflict and confusion.

The Weather Bureau maintains storm warning display stations at numerous ports along the coasts affected by hurricanes. A systematic plan for obtaining special weather, tide and swell observations from those places is a part of the program.

At the present time all hurricane warnings and advisories are included in a bulletin specially designed for the use of masters of ships at sea and are broadcast twice daily through the naval radio station (NAA) at Arlington, Va. This bulletin is copied by other naval stations and rebroadcast so that all ships in waters subject to tropical storms are warned. This service will be continued. Warnings issued from San Juan, Jacksonville, and New Orleans will be telegraphed to Washington for inclusion in the bulletin. In addition, a special bulletin containing weather information, forecasts, hurricane warnings, etc., will be broadcast twice daily during the hurricane season and on fixed schedules from the naval radio station at Key West, Fla. It is expected that commercial radio stations will cooperate similarly in the distribution work.

A unique and important feature of the reorganization will be a teletypewriter set-up during the five active hurricane months. This system is designed for speedy collection of observations from life saving and storm warning stations, the distribution of land and ship reports from one forecast center to the other, including intervening first order stations, and immediate dissemination of warnings and advices to the entire coastal area. This teletype circuit will connect the Weather Bureau forecast centers at Jacksonville and New Orleans and its offices at Tampa, Miami, Key West, Pensacola, Mobile, Port Arthur, Houston, Galveston, Corpus Christi, and Brownsville. The teletype circuit will operate 24 hours a day, every day in the week, including Sundays and holidays, and will be used exclusively by the Weather Bureau.

A forecaster will be on duty night and day at Jacksonville and New Orleans and trained observers will be on watch constantly at all the other offices having teletype installations. In this way advantage will be taken of every weather report that has significance, the forecaster will be in continuous touch with the local Weather Bureau officials and through the latter the newspapers and the public will be kept fully and promptly informed.

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CHRONOLOGY

1831. Capt. William Reid began hurricane studies on the island of Barbados.
1838. Reid published his laws of storms.
1847. Reid established display of signals at approach of storms.
1870. Father Benito Viñes became director of Belen College and inaugurated a hurricane-forecasting service, for Cuba.
1870. February 9: United States Congress made appropriations for a national meteorological service.
1873. August 6: Daily reports from Cuba and other West Indies islands first received.
1875. September 11: Father Viñes issued first hurricane warning.
1876. Set-back in development of hurricane-warning service due to discontinuance of reports from West Indies.
1881. West Indian reports again suspended; legality of expenditures outside of United States questioned.
1889. January 1: Meteorological service for Cuba organized under direction of Naval Observatory of Cuba.
1898. First reorganization of hurricane-warning service to protect American fleet during Spanish-American War; bill for providing funds submitted to Congress June 16; approved July 7.
1898. July 25: First observing station opened at Kingston, Jamaica, which was made headquarters of hurricane-warning service.
1899. February 1: Headquarters of forecasting service transferred to Habana.
1902. Forecasting service for hurricanes transferred from Habana.
1902. National Meteorological Service of Cuba established.
1919. June 1: Hurricane-warning center for Puerto Rico established at San Juan.
1935. July 1: Second reorganization of hurricane-warning service; service transferred from Washington to centers at Jacksonville and New Orleans.

EFFECT OF THE ATLANTIC OCEAN ON TEMPERATURES IN EASTERN UNITED STATES AS SHOWN BY TEMPERATURE-WIND ROSES [1]

By KATHARINE B. CLARKE

[5814 Thirty-second Street NW., Washington, D. C., March 1935]

In the preparation of a thesis concerned with some effects of the Atlantic Ocean upon the climate of eastern United States, a study was made of the effectiveness of the ocean in moderating temperatures at various stations. The decrease in temperature ranges along the Atlantic coast is obvious from maps of the average daily range of temperature (figs. 82, 83, and 84, p. 25, *Atlas of American Agriculture*, Pt. II, Climate, Sec. B, Temperature, Sunshine, and Winds, United States Department of Agriculture, Washington, D. C., 1928); there is a very much smaller daily range along the immediate seashore than inland. The Brownsville region, southern tip of Florida, Cape Hatteras and Cape Cod have in spring, summer, and fall the small daily range of 9° to 12° F. A comparison of the highest and the lowest recorded temperatures (fig. 3, p. 7, and fig. 6, p. 8, *Atlas of American Agriculture, loc. cit.*) shows a pronounced moderating effect of the Atlantic Ocean along the coast, but indicates that this does not extend westward beyond the Appalachian Mountains.

To show, by some quantitative and graphical means, the influence of winds from the direction of the Atlantic Ocean upon the temperatures of coastal and inland stations, temperature-wind roses were constructed: Data used for these roses were the 8 a. m. readings of temperature and wind-direction published on the Washington daily weather maps. Seventeen stations in eastern United States were chosen, and data for 20 years (1906–25) for the months of January and July were compiled and averaged. For each station the following data were obtained: (1) Average 8 a. m. temperature; (2) frequency of winds from the cardinal and semicardinal points; (3) average temperatures with winds from each direction; (4) the departure, from the 8 a. m. average temperature, of these average temperatures for each wind-direction.

From this information the roses were constructed, as illustrated by figure 1, the January and July roses for Boston: The center part is a simple frequency wind rose. On the 620 January days, Boston had a northwest wind 149 times and a southeast wind 23 times. At a convenient distance from the center of the rose (the same distance for all directions and for all roses), a point was chosen as a zero from which to plot temperature departures; minus departures were represented inside the zero point, and plus departures outside. A polygon, which is a perfect octagon, connects the zero points and represents the simple average 8 a. m. temperatures for the 620 days. A heavy line connects the points that represent the departures; it forms the temperature-wind rose, a distorted polygon. The amount and kind of distortion represents the effect upon temperature of winds from the different directions; on the Boston January rose, for example, the mean departure with a northwesterly wind is minus 7.7°, and with a southeasterly wind, plus 7.5°.

Unfortunately it is almost impossible to make a correction for the different latitudes from which the winds come; southerly winds usually bring warmer air, and northerly winds colder air. The greatest interest is in winds from easterly directions, as the purpose of the

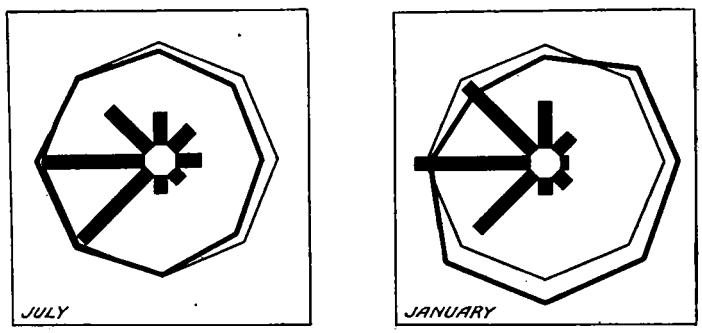

FIGURE 1.

roses is to measure, if possible, marine influence. Local conditions of topography will affect almost every station; Albany, for example, has a very decided minus departure in winter with southeasterly and easterly winds as well as with northeasterly winds, since easterly winds bring colder air from the nearby highlands.

These temperature-wind roses were placed on a map of the eastern United States in their respective positions. Figure 2 shows the roses for January so placed; for purposes of better reproduction, the zero polygons have been changed to broken lines. The distortion of the solid-line polygons indicates that departures from the average are greatest along the New England coast. The roses very clearly show the plus departures with easterly, southeasterly, and even northeasterly winds. This plus departure with an easterly wind in January does not appear at

[1] A part of a thesis submitted to the Faculty of Clark University, Worcester, Mass., June, 1930, in partial fulfillment of the requirements for the degree of master of arts in the department of geography.